International Atomic Energy Agency

Overview of Activities Conducted and Planned in Small & Medium Water Cooled Reactors (SMRs)

Group C

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Division of Nuclear Power

TWG Meeting on Advanced Technologies for LWRs & HWRs, 26-28 July 2010, Vienna, Austria

Outline

- Background
- Roles of IAEA on SMRs
- Options of SMRs for Near Term Deployment
- IAEA"s Projects on SMRs
- Selected Common Areas of Supports for SMR
- IAEA's Coordinated Research Project (CRP)
- Conducted and Planned TMs in 2010 – 2011
- Today's Brainstorming Plan for Group C
- Summary

Background

- Continuing interest in Member States in the development and application of Small & Medium-sized Reactors (SMRs)
- Some developing countries with small electrical grids and insufficient infrastructure plan to adopt SMRs as affordable nuclear power option
- The General Conference resolution GC(53)/RES/13/Tab B.3/09-2009 calls for the promotion of effective international exchange of information on options regarding SMRs available for deployment, then address issues such as operational performance, maintainability, safety and security, constructability, economics, proliferation resistance, and the state of development of innovative SMRs, by organizing workshops and too produce status report;

Background (cont'd)

- The GC resolution encouraged the Secretariat to continue the activities of the Regular Budget project "Common Technologies and Issues for SMRs" on both the development of key enabling technologies and resolution of key infrastructure issues for innovative SMRs, complementary to extra-budgetary for International Project on Innovative Nuclear Reactors and Fuel Cycle (INPRO).

Definition and SMR Developments in Member States

- Small-sized reactors: < 300 MW(e)
- Medium-sized reactors: < 700 MW(e)
- Power limit for medium size may change since the current large-reactors are up to 1700 MW(e)
- Until recently, several dozens of Design Concepts of Innovative SMRs have been developed in **Argentina**, **China**, **India**, **Japan**, the **Republic of Korea**, **Russian Federation**, **South Africa**, **USA**, and several other IAEA Member States

Roles of IAEA on SMRs

- Coordinates efforts of Member States to facilitate the development of SMRs by taking a systematic approach to the identification of key enabling technologies to achieve competitiveness and reliable performance of SMRs, and by addressing common issues to facilitate deployment
- Establishes, develops, and maintains an international network with international organizations involved on SMRs activities
- Ensures overall coordination of Member States experts participating in SMR activities by planning and implementing training and by facilitating the sharing of information and experience, also transfer of knowledge
- Develops international recommendations and guidance on SMRs with a view especially to addressing specific needs of developing countries

SMRs - Options for Near-Term Deployment

PWRs with integrated design of primary circuit

- **IRIS - Westinghouse (USA) + Intl. Team**
- **mPower – Babcock & Wilcox (USA)**
- **NuScale - NuScale, USA**
- **CAREM – CNEA, Argentina**
- **SMART – KAERI, the Republic of Korea, and several others**

PWRs – marine reactor derivatives

- **KLT-40S *(Floating NPP)* – Rosenergoatom, Russia**
- **ABV (Floating NPP) – Rosenergoatom, Russia**
- **VBER-300 *(Land based NPP)* – Rosatom + Government of Kazakhstan, Rosatom**

Advanced Light Boiling Water Cooled Heavy Water Moderated Reactors, Pressure Tube Vertical Type

- **AHWR (incorporating Th fuel) – BARC, India**

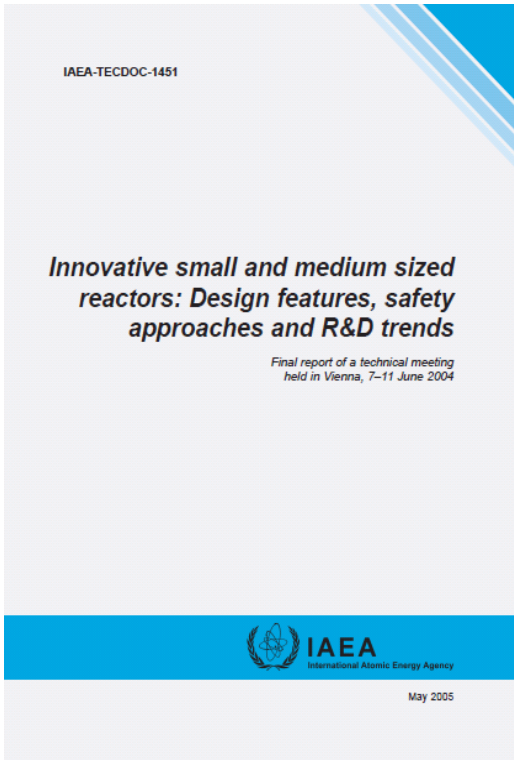
High Temperature Gas Cooled Reactors

- **HTR-PM – INET, China**

Heavy Liquid Metal Cooled Reactors

- **SVBR 100 – En+, Russian Federation**

Project "Common Technologies and Issues for Small and Medium Sized Reactors (SMRs)"
P&B 2010-2011: 1.1.5.5



Objective:

➢To facilitate the development of key enabling technologies and the resolution of enabling infrastructure issues common to future SMRs of various types

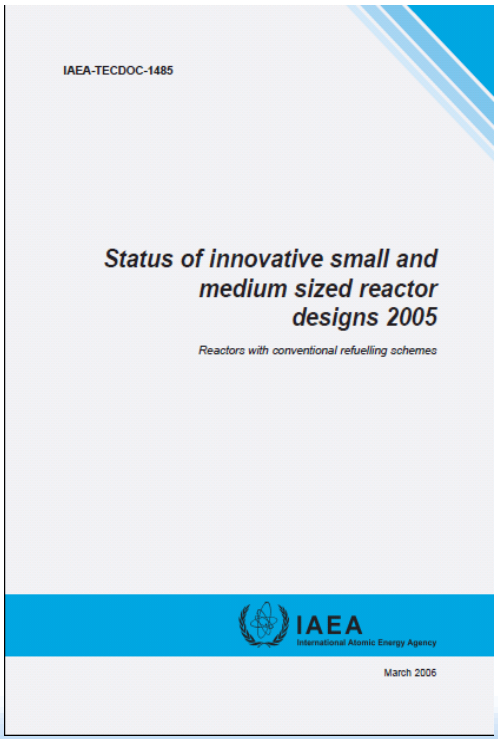
Expected outcome:

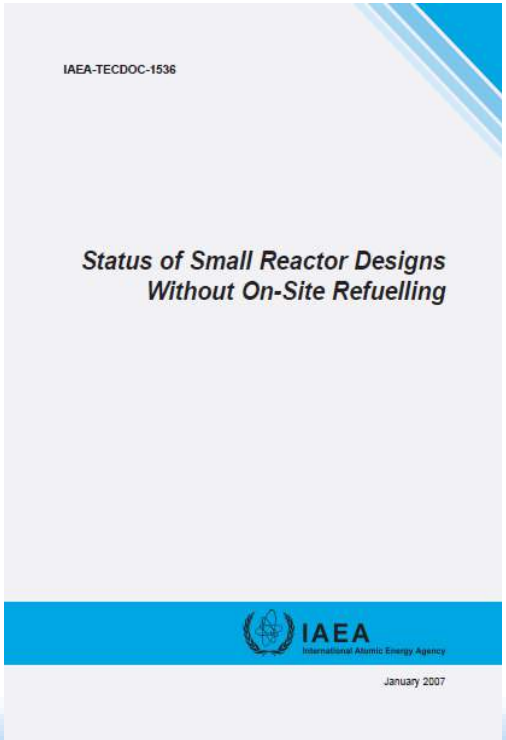
➢Increased international cooperation for the development of key enabling technologies and the resolution of enabling infrastructure issues common to future SMRs of various types

Status Reports of Advanced SMR Designs

- **INTERNATIONAL ATOMIC ENERGY AGENCY, Status of Innovative Small and Medium Sized Reactor Designs 2005: Reactors with Conventional Refuelling Schemes, IAEA-TECDOC-1485, Vienna (March 2006)**

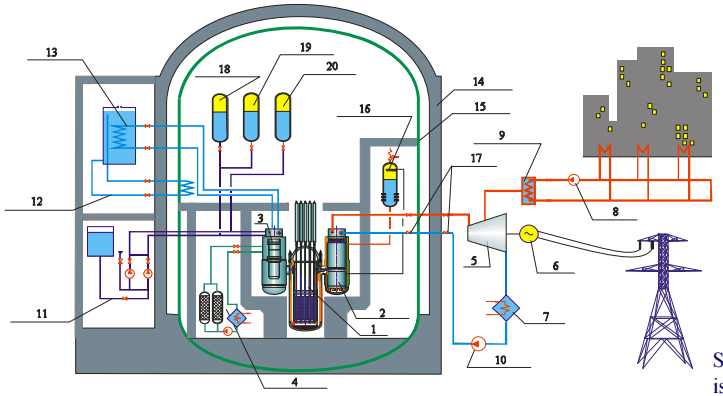
- **INTERNATIONAL ATOMIC ENERGY AGENCY, Status of Small Reactor Designs without On-site Refuelling, IAEA-TECDOC-1536, Vienna (March 2007)**

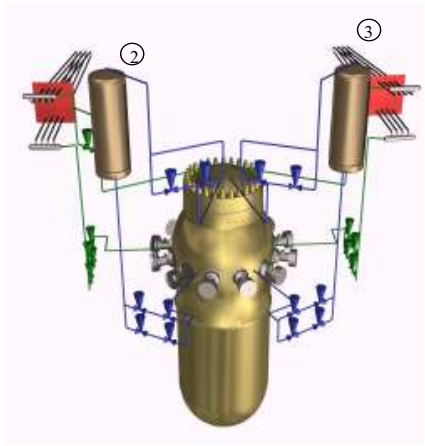


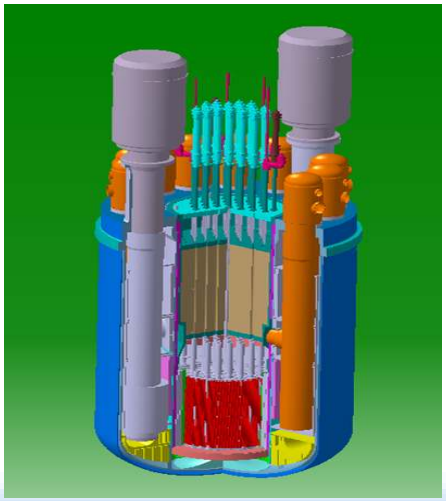


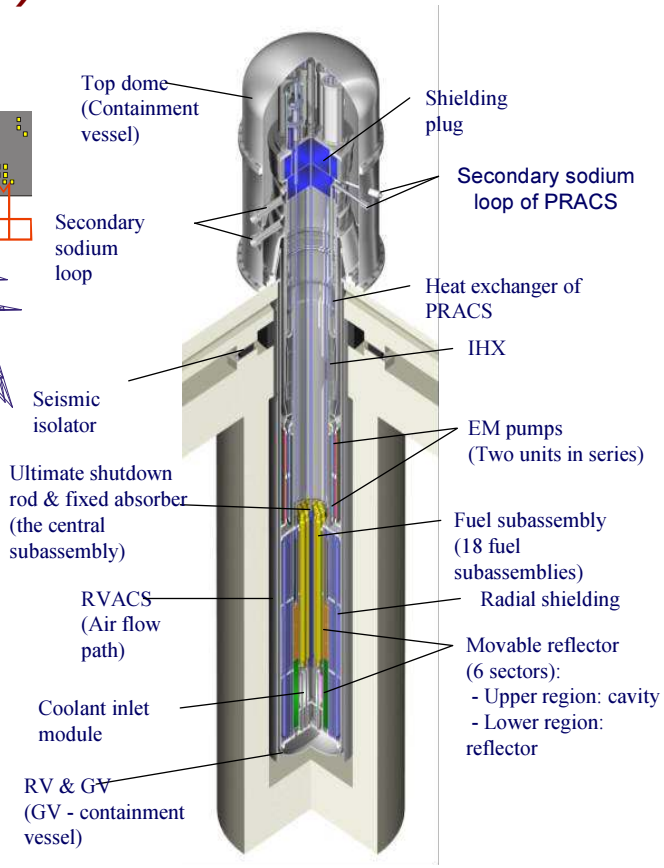
New Activity: SMR Design Descriptions for Advanced Reactor Information System (ARIS)

- ***Updating the Format for SMR design description***
- ***Design descriptions of advanced SMRs collected from Member States***
- ***Developing Database format and software (NPTDS)***



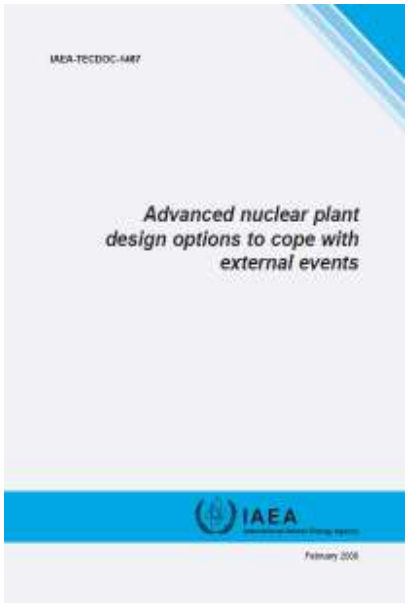


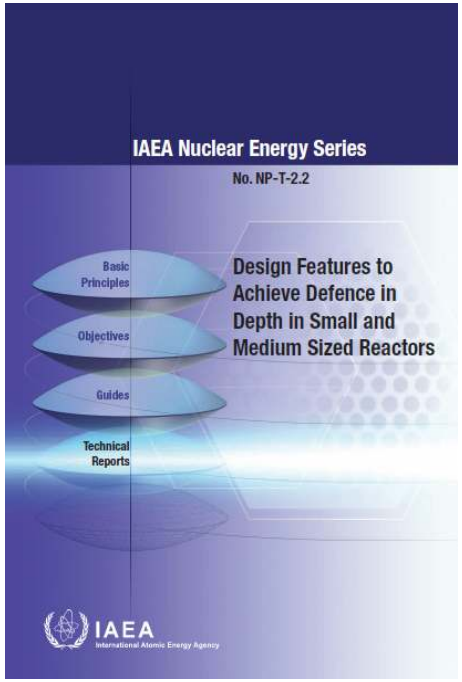




Selected Common Areas of Technology and Infrastructure Development in Support of Advanced SMRs

➢Design for External Events





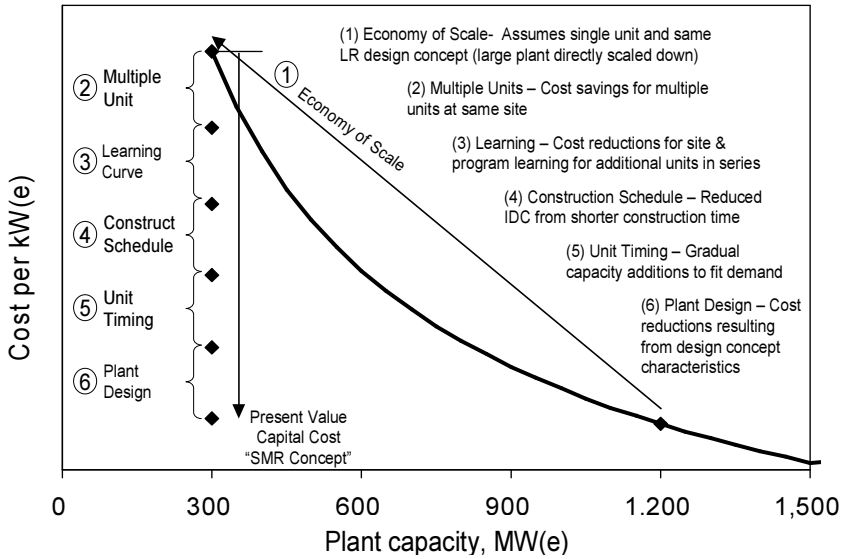
➢Design Features to Achieve Defence in Depth in SMRs

➢Methodology to Revise Emergency Planning Zone Requirements

✓**INTERNATIONAL ATOMIC ENERGY AGENCY, Final Report of a CRP on Small Reactors Without On-site Refuelling, IAEA-TECDOC (to be Published in 2010)**

Selected Common Areas of Technology and Infrastructure Development in Support of Advanced SMRs

➢Approaches and Tools to Assess Competitiveness of SMRs



Note 1 - IDC: Interest during construction

FIG. 8. Generic view of factors affecting comparative costs of SMRs and large reactors.

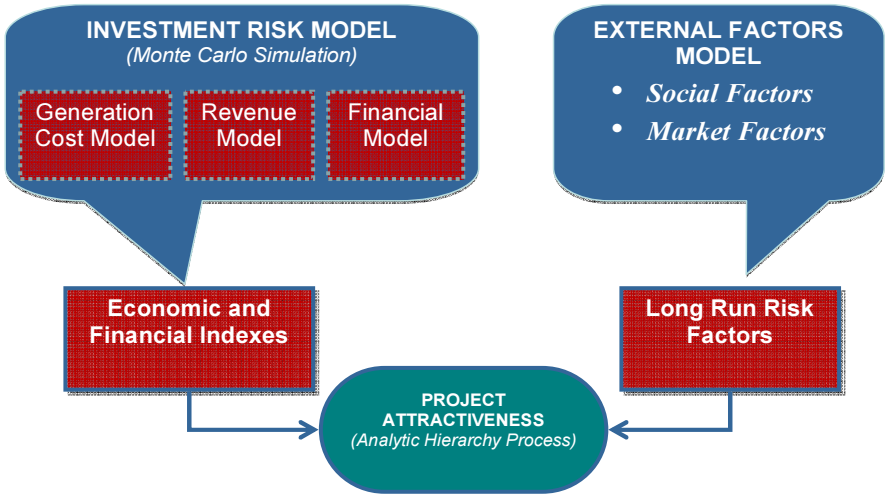


FIG. 14. Schematics of the integrated model for competitiveness assessment of SMRs (INCAS, Politecnico di Milano, Italy)

✓INTERNATIONAL ATOMIC ENERGY AGENCY, Approaches to Assess Competitiveness of SMRs, Nuclear Energy Series Report (to be published in 2010)

➢Options to Enhance Proliferation Resistance and Physical Protection of NPPs with Innovative SMRs

✓Multiplicity of SMRs or their remote location may pose proliferation resistance and physical protection challenges

✓A report will be developed to provide a framework for the application of PR &PP assessment methodologies to evaluate PR&PP features of innovative SMRs and associated fuel cycles beginning in the early design stages and, progressively, as the design matures

A Technical Meeting was held on 8 – 11 June 2010 in IAEA - Vienna

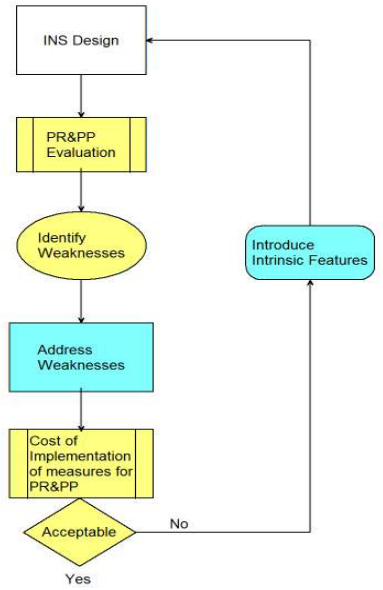
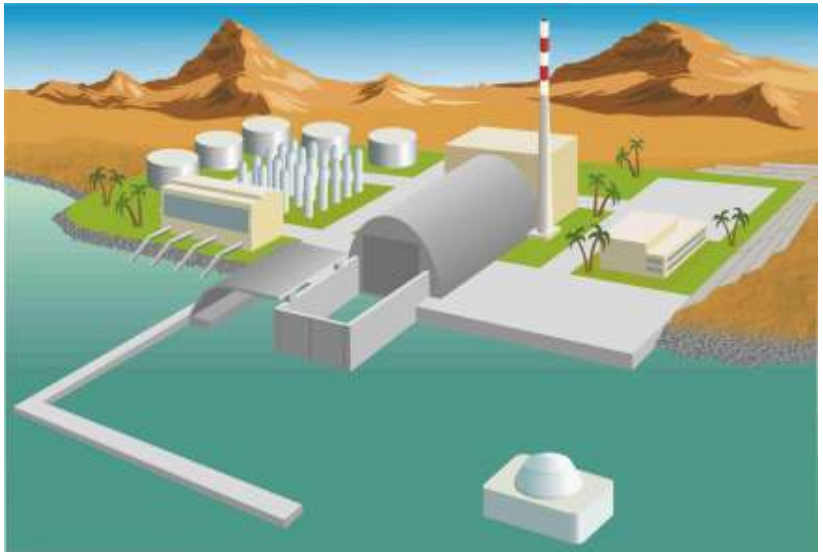


Fig. 1. General framework of the proliferation resistance and physical protection assessment at different design stages of an innovative SMR and associated fuel cycle.

Selected Common Areas of Technology and Infrastructure Development in Support of Advanced SMRs

- Cooperation with INPRO on Legal and Institutional Issues for Transportable NPPs
  - ✓Definitions
  - ✓Technical features affecting infrastructure solutions



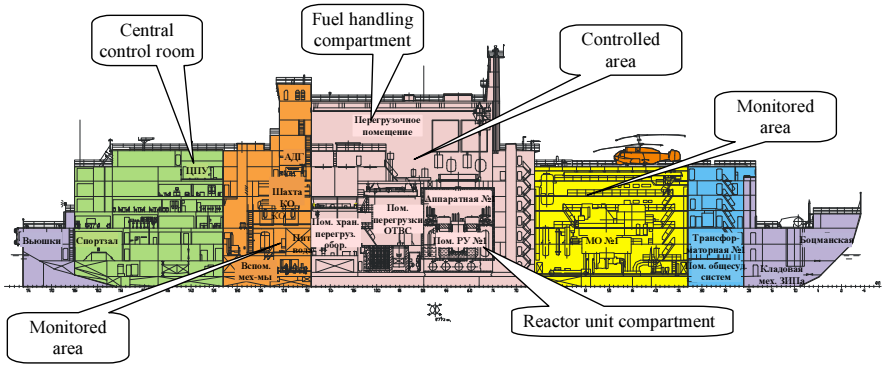


FIG. I-2. Floating power unit with two KLT-40S nuclear installations.

CRPI31018 "Development of Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors" (2009-2011)

In Conjunction with Technical Working Groups on Advanced Reactors
- Nuclear Power Technology Development Section of the NE, and
- Safety Assessment Section of the NS

The objective is to determine a common analysis-and-test method for reliability assessment of passive safety system performance

The method would facilitate application of risk-informed approaches in design optimization and safety qualification of the future advanced reactors, contributing to their enhanced safety levels and improved economics.

CRP I31018 "Development of Methodologies for the Assessment of Passive Safety System Performance in Advanced Reactors"

➢**The participants are:**

CNEA (Argentina)
BARC (India)
IGCAR (India)
CEA (France)
ENEA (Italy)
University of Pisa (Italy)
OKB "Gidropress" (Russia)
Idaho State University (USA)

+ *Observers from Japan and Sweden*

➢First Research Coordination Meeting (RCM-2) was convened on 31 March - 3 April 2009 in Vienna, Austria

➢Detailed work plan and schedule for 2009 - early 2010 was defined and implemented

➢Second RCM was held in Vienna on 16 – 19 March 2010

Conducted and Planned TM in 2010 - 2011

- TM on Preparation of a NE Series Report "Options to incorporate Intrinsic Proliferation Resistance Features to NPPs with Innovative SMRs" – conducted on 8 -11 June 2010
- TM on Preparation of Status Report on Innovative SMR Designs with Potential Deployment by 2020 – planned for 19-22 October 2010, but modified into a Workshop to be held in March 2011
- TM on Preparation of a Chapter on Development Status and Prospects for Advanced Computation Methodologies using CFDs for Single- and Two-Phase Coolant Flows – planned for 17-19 November 2010, but modified as a Joint Meeting/Efforts with TWGs for LWR/HWR for 2011
- TM on the Publication on Options to Enhance Energy Supply Security with NPPs based on SMRs – planned for 14-17 December 2010, but will be postponed and rescheduled during the current TWG meeting.

Brainstorming for Group C
SMR Activities for 2012-2013 P&B

- How to address the GC resolution in practical way? – strategic direction, lesson-learned and wisdom …
- How to formulate so that the Group can give meaningful added values to SMR development and deployment?
- How to address institutional and licensability issues specific to SMR?
- How to facilitate new technology development?
- How to address prominent issues of economics, financing scheme, operational performance, and so forth?
- How to support near term deployment and promote partnership for development?
- Finalize plan for 2010 and 2011

Summary

- SMRs may provide an attractive and affordable nuclear power option for developing countries with small electrical grids, insufficient infrastructure and limited investment capability
- Multi-module power plants with SMRs may offer energy production flexibility in the current and future deregulated energy market
- SMRs are of particular interest for co-generation and many advanced future process heat applications
- SMR designs may reduce challenges on spent fuel and waste management and offer greater non-proliferation assurances to the international community
- The Innovative SMR concepts have several common technology development issues related to licensability, economic competitiveness, plant-siting, optimum financing scheme, proliferation resistance and security, long refuelling interval and operation without on-site refuelling

THANK YOU

For questions and requests, please contact:

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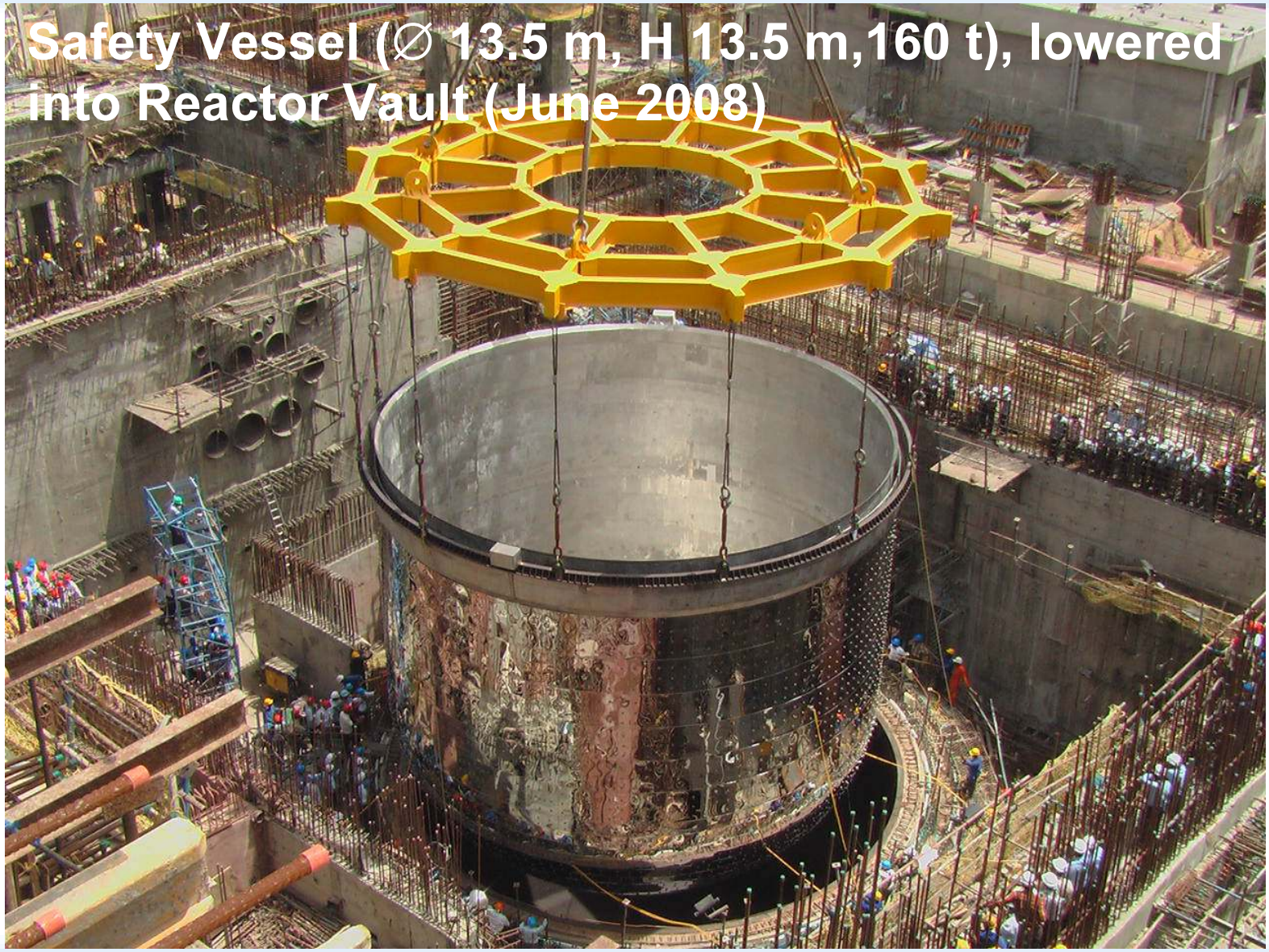
Visit our Web page:

http://www.iaea.org/NuclearPower/SMR/

Back Up Slides

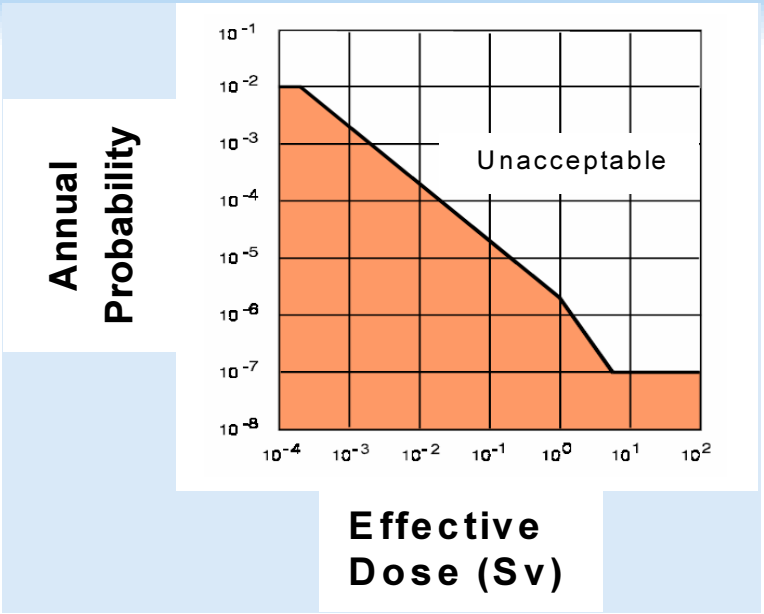
India's 500 MWe Fast Reactor-Commissioning 2011



Risk-Informed Approaches

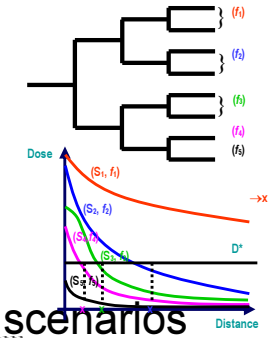
Risk-informed Methodology to redefine EPZ . The requirements has been developed within IAEA CRP "Small Reactors without On-site Refuelling" (2004-2009)

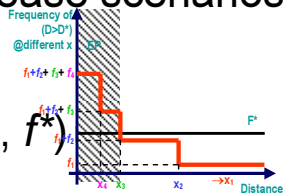
Argentina's regulations (severe accidents)

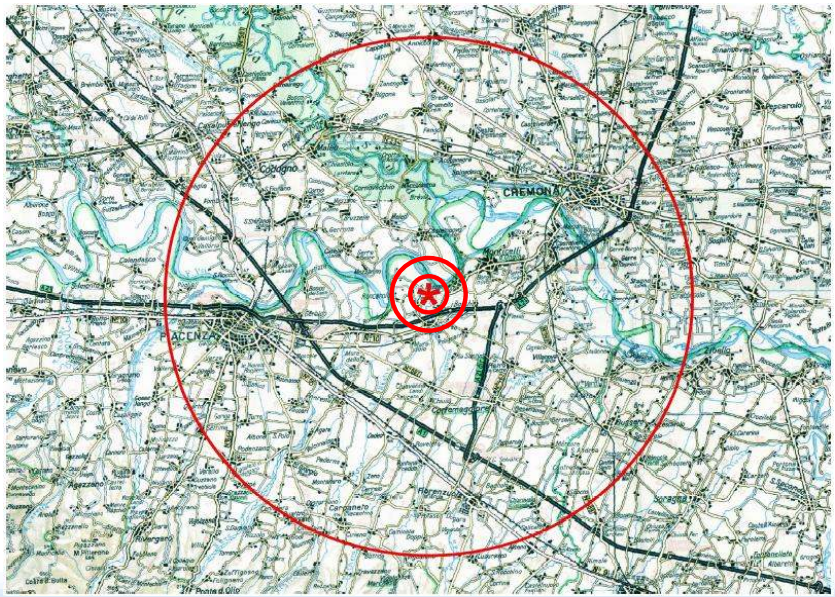


EPZ Redefinition Methodology

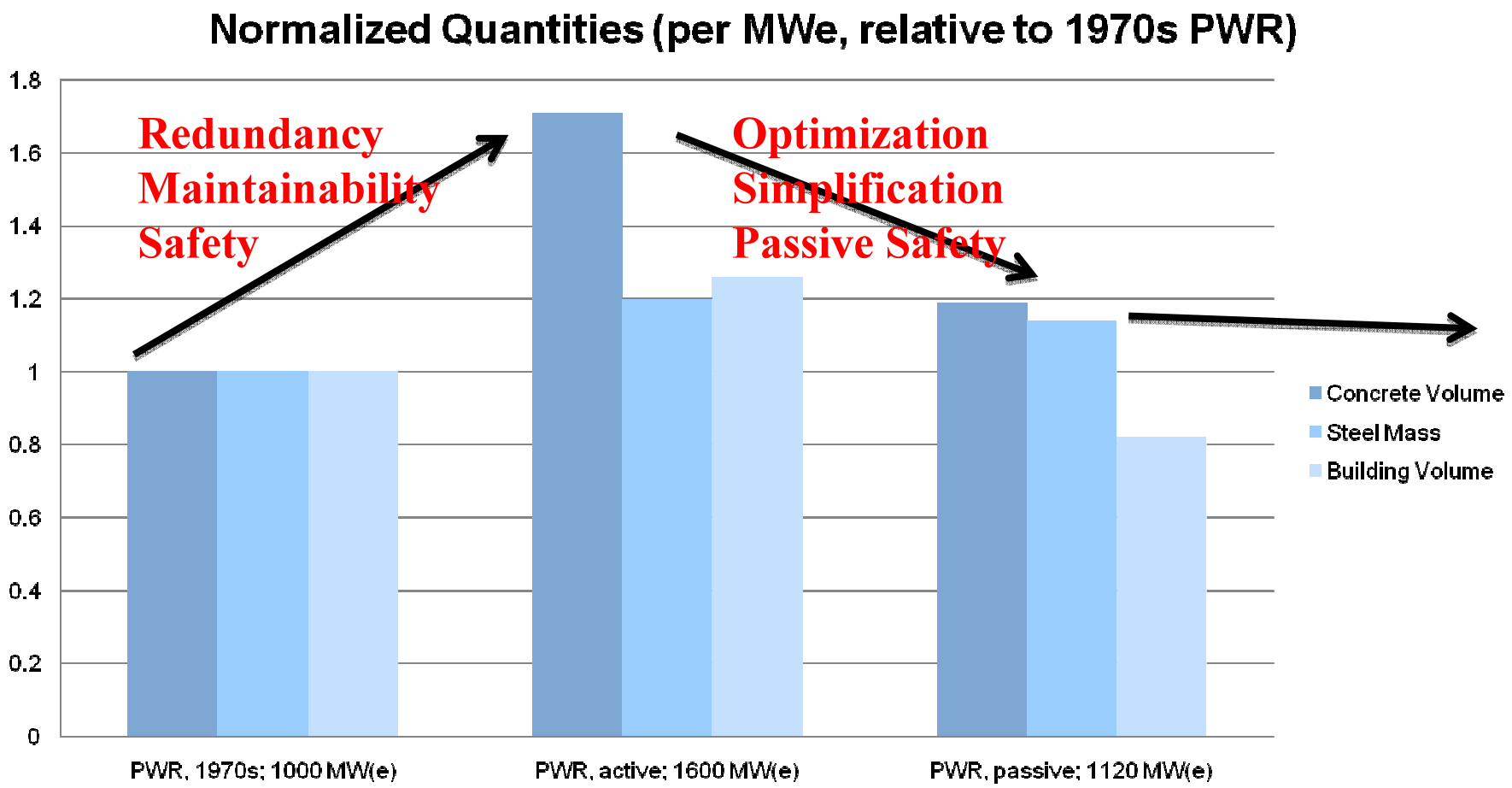
- Step1
  PRA accident sequences re-categorization
  and release scenario definition
- Step2
  Deterministic dose vs distance evaluation for relevant release scenarios
- Step3 (Limiting dose, D*)
- Step4 (Limiting frequency, *f**)
- Step5 (EPZ definition)



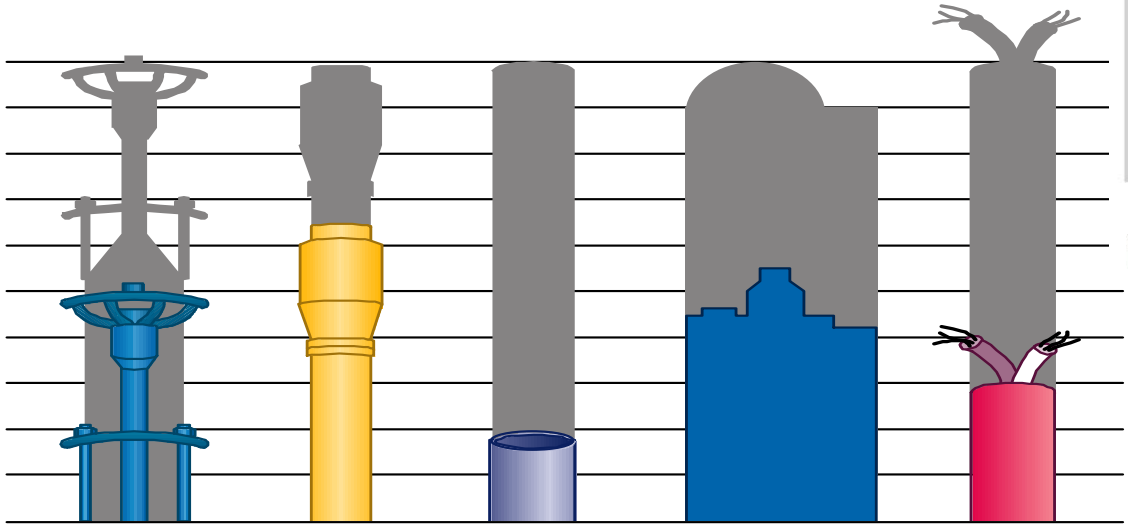




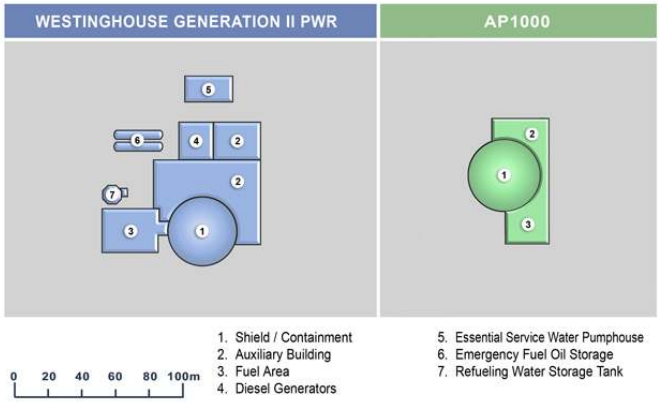
Evolution of PWR's – 70's to now to ?



Latest passive designs had major simplification
- what systems/functions (~100) will be eliminated?
- will that impact availability, maintainability?



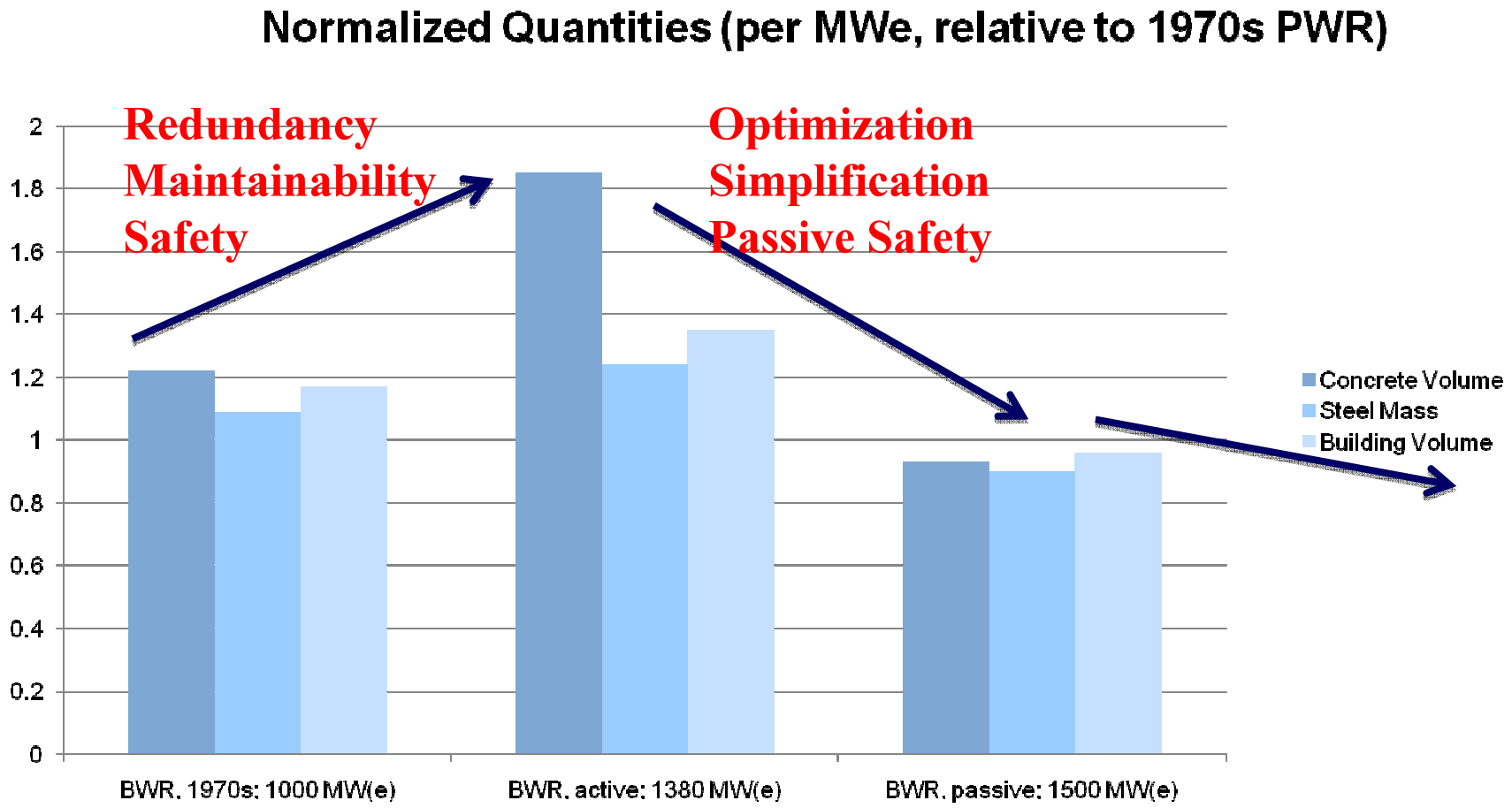
50% Fewer Valves | 35% Fewer Pumps | 80% Less Pipe | 45% Less Seismic Building Volume | 85% Less Cable



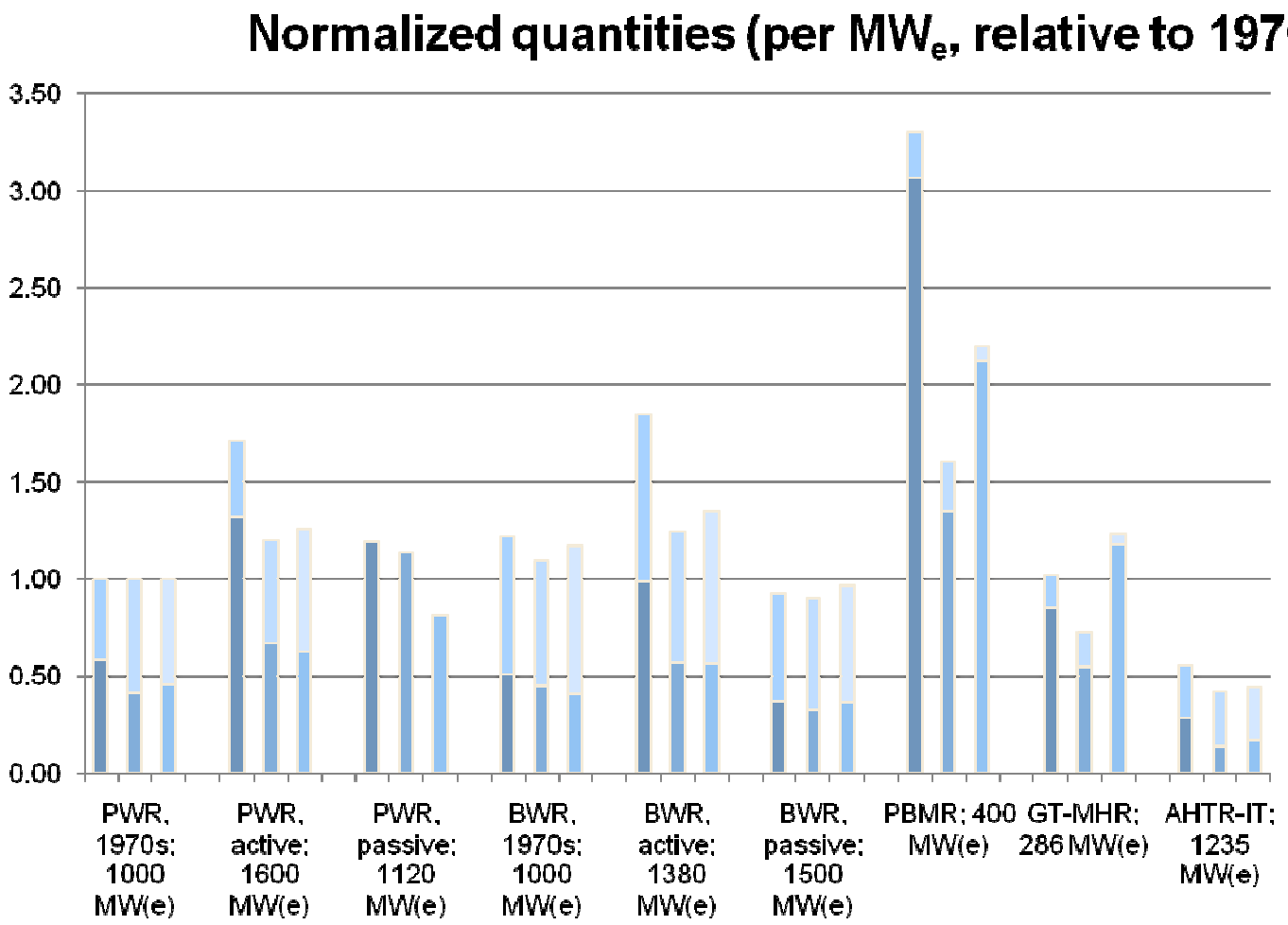
Comparison of Building Volumes

Through the Courtesy of Westinghouse, Technical Brochures on AP600

Evolution of BWR's similar to PWR's



Evolution of Technology
(Variation of material quantities over time)



1970s PWR:
-Building volume, total = 336 m^3/MW_e
-Steel mass, total = 37 t/MW_e
-Concrete volume, total = 75 m^3/MW_e

N.B. The passive PWR data are estimates based on available data. Values for the entire plant are plotted as "nuclear" in lieu of a "nuclear" and "non-nuclear" breakdown.

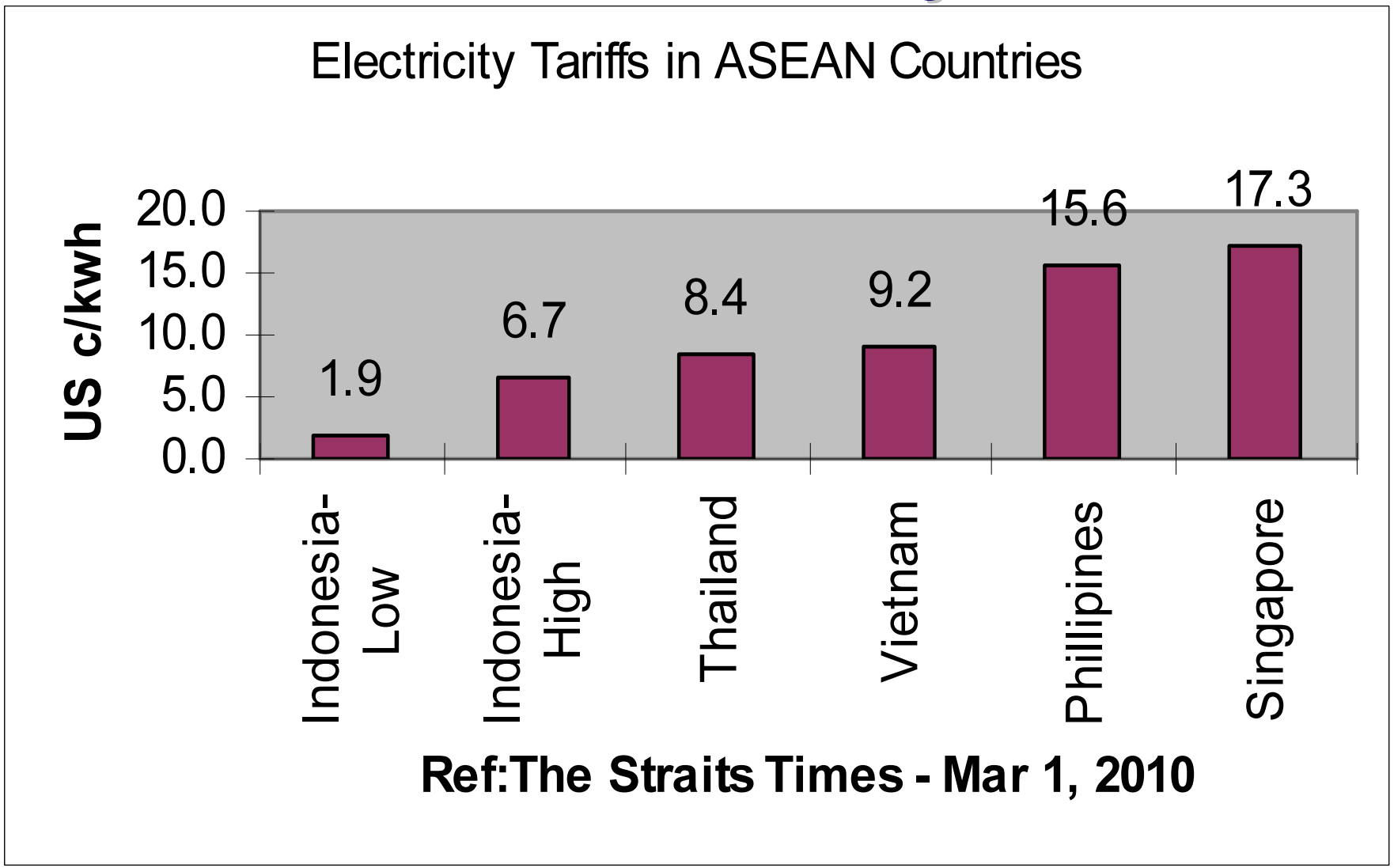
P.F. Peterson et al. "Metal and concrete inputs for several nuclear power plants"; Westinghouse & estimates

Trends in advanced plant design

- Increase plant availability
  - Use proven, reliable components and materials
  - Design for maintenance – online or during outage
  - Add redundancy for crucial components
- Reduce plant components – simplify
  - Use modern plant control systems
  - Use fewer and larger components
  - Combine or eliminate functions of systems
  - Rely on economy of scale
- Design for easier & shorter construction
  - Increased use of structural and system modules
  - Complete and standardized designs with pre-licensing
- Build safety into the design
  - Increased margins and use of lessons learned
  - Increase redundancy and diversity or use passive systems

Relying on 50 years of experience

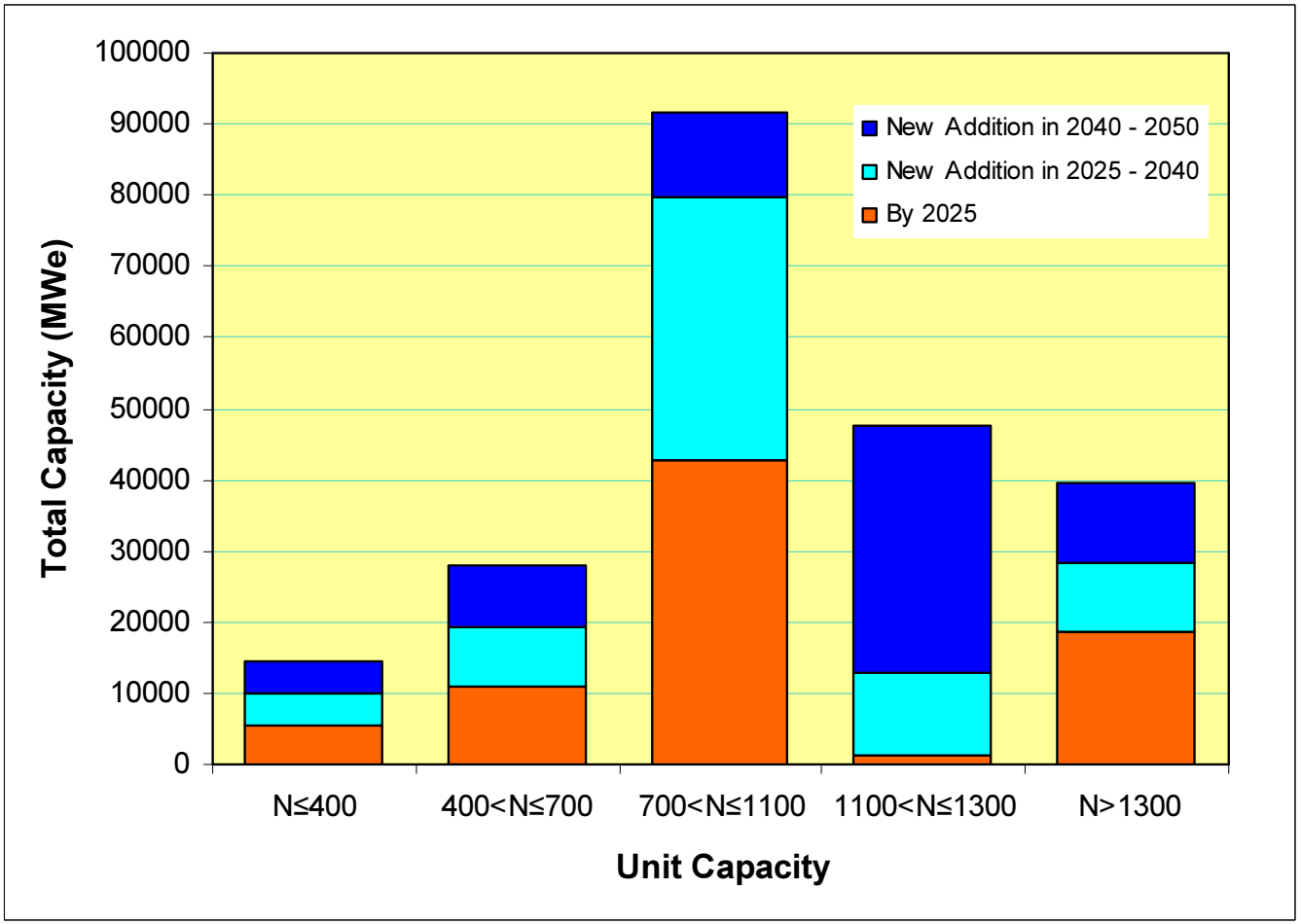
Variation in Electricity Tariffs



Generation Costs and Tariffs

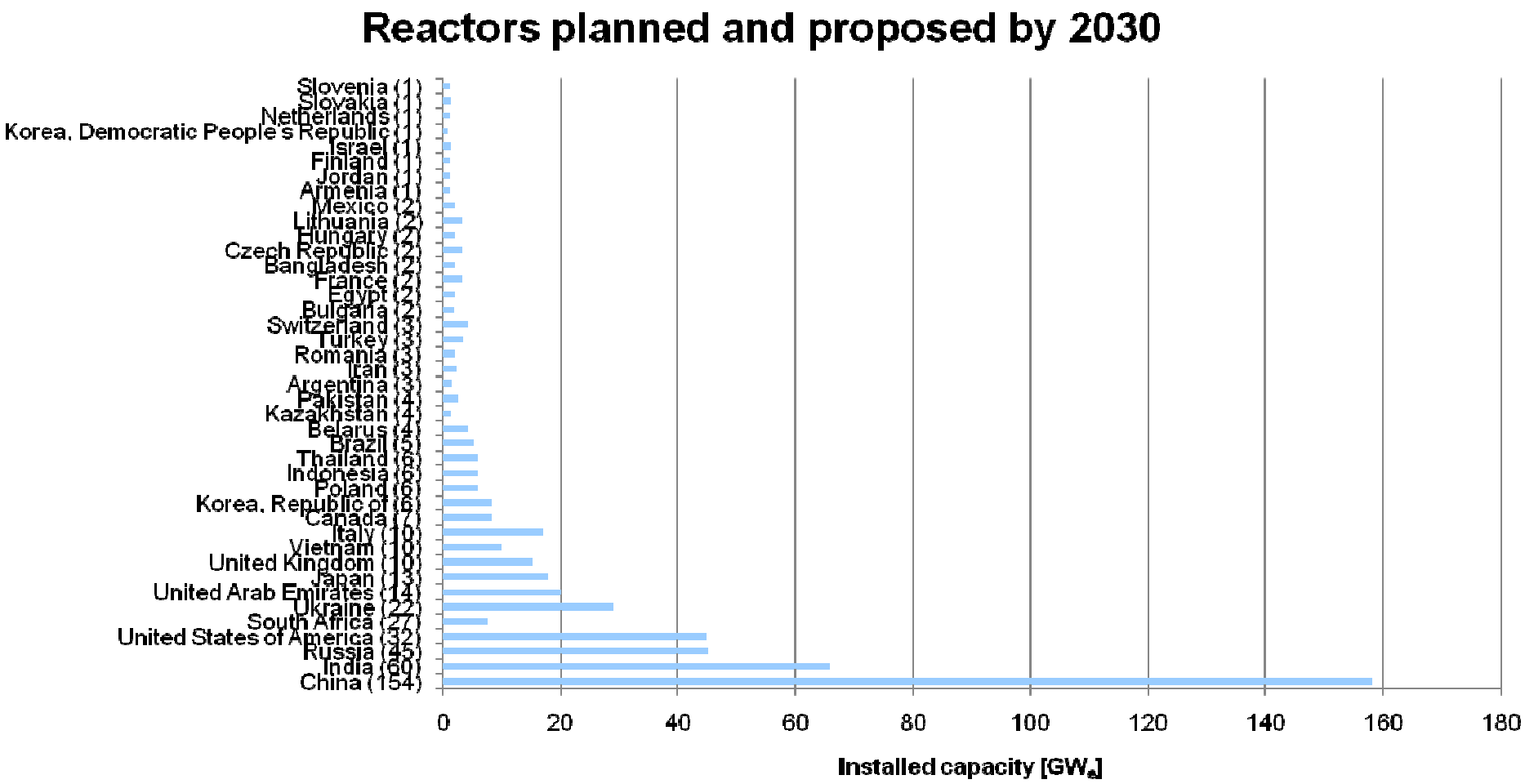
- Electricity generation costs for different options vary considerably across countries
- Economic evaluations need to consider generation, transmission and other costs
- Subsidies effect the costs (tariffs) paid by the consumers

Total new capacity at different unit sizes
(Expectations from "User" countries, derived from survey)



User Countries – 50 developing countries excluding China/India

NPPs planned & proposed by 2030



Source: WNA World Nuclear Reactors and Uranium Requirements; accessed May 2010